METHOD AND PUMP APPARATUS FOR REMOVING LIQUIDS FROM WELLS

DESCRIPTION

CROSS REFERENCE TO RELATED APPLICATIONS

[Para 1] This application is a continuation in part (CIP) of co-pending application Ser. No. 10/926,424 filed August 26, 2004, the entirety of which is incorporated herein by reference.

Field of the Invention

[Para 2] The present invention relates generally to methods and systems for lifting fluids from a well. More particularly, relating to a method and apparatus for removing formation fluid, such as water from a low production gas well to reduce static pressure within the well created by the formation fluid, thereby increasing production of gas from the well.

Discussion of the Prior Art

[Para 3] Many gas wells experience decreased gas production over the service time of the well, and some eventually cease gas production completely. Factors causing this problem include declining reservoir pressure and gas velocities, and increased liquid production. The increased liquid production can results in a column of liquid to accumulating at the bottom of the well, preventing reservoir fluids (gas) from entering the wellbore. This accumulation of liquid is called “liquid loading of the well”.

[Para 4] There are many systems available to restore a well that is "liquid loaded" back to flow production, such as a siphon string (or velocity string), a plunger lift, a pump jack, and a submersible pump.

[Para 5] A siphon string is essentially a small diameter tubing string that is lowered into the production string of a well. The siphon string provides a reduced cross-sectional flow area which increase the gas velocity in the tubing. The higher gas velocity at the bottom of tubing provides more transport energy to lift fluid up out of the well. Liquid no longer accumulates at the bottom of the well, and production is sustained. Siphon strings are very difficult to size properly so that the gas velocity meets or exceeds a minimum or critical velocity to prevent the well from loading up. The process of determining the correct size of the tubing string is well described by Turner et al. in "Analysis and Prediction of Minimum Flow Rate for the Continuous Removal of Liquid from Gas Wells"; J. Pet. Tech (Sept. 1969) 1475-1481.

[Para 6] A plunger lift is an artificial-lift method principally used in gas wells to "unload" relatively small volumes of liquid. An automated system is employed to control the well on an intermittent flow regime. When the well is shut-in, a plunger is dropped down the production string and then when the control system opens the well for production, the plunger and a column of fluid are carried up the tubing string. A surface receiving mechanism detects the plunger when it arrives at the surface and, through the control system, prepares for the next cycle. One deficiency of a plunger lift system in the amount of time required for each cycle of the system. Typically gas wells are medium to deep wells and plunger must travel a great distance up and down the well to lift fluid.

[Para 7] A pumpjack is another artificial lift method and basically includes a plunger pump submerged into the well below the volume of water and is actuated by a rod string that extends to the surface, which is reciprocated by a

prime mover at the surface. A pump jack is an old fashion system and is prone to wear resulting in down time required to make necessary repairs.

[Para 8] The use of a submersible pump is yet an additional method of "unloading" the well, which involves placing the pump at the bottom hole and positively pumping the fluid to the surface of to "unload" the well. Submersible pumps are limited to the depth of the well and become less efficient in operation the deeper the well is. Additionally, electrical submersible pumps are typically used which requires the drop-in of an electric control line and electric power line.

[Para 9] While the above described systems operate as intended, there exists a need for a more efficient method and apparatus for "unloading" a well, as such the method and apparatus of the instant invention provides such a method and apparatus which is more efficient, less costly to operate, experiences less wear, and has a reduced cycle time.

SUMMARY OF THE INVENTION

[Para 10] In accordance with the present invention, an apparatus and method for efficiently removing fluid from a well is provided. The apparatus is relatively inexpensive to manufacture as it incorporates readily available components and is inexpensive to operate due to a low electrical load requirement, which can be met by using solar power systems or by a small electric generator. The low power requirement make the instant invention very conducive for operation with wells that do not have access to wired electrical power.

[Para 11] In one embodiment, the apparatus essentially includes a pump body having an exterior surface and an axial bore comprising a first chamber and a second chamber which are separated by a diametrically reduced section of the axial bore. The pump body further includes at least one gas vent which extends from the exterior surface of the pump body into the first chamber, a fluid inlet port extending from the exterior into the second chamber, and a fluid discharge port extending from the exterior surface and into the second chamber. A hydraulic head is attached to the pump body and a displacement plunger extends from the hydraulic head through the axial bore. A hydraulic circuit is attached to the hydraulic head and is operated to control reciprocation of the displacement plunger within the axial bore by the hydraulic head. A vent passage extends through a distal end of the displacement plunger for venting gas therethrough from the second chamber into the first chamber and then finally through the gas vent of the pump body. A fluid discharge conduit is connected to the fluid discharge port and includes a first check valve connected inline therewith allowing fluid to be discharge in only one direction from the second chamber out of the discharge port and into a lift tube, which is connected to the fluid discharge conduit. A second check valve is connected to the fluid inlet port for allowing formation fluid to flow in one direction into the first chamber of the pump body.

[Para 12] In a second embodiment, the apparatus essentially includes a pump body having an exterior surface and an axial bore. A fluid inlet port extends from the exterior surface of the pump body into the axial bore, a fluid discharge port extends from the exterior surface into the axial bore, and a vent port extends from the exterior surface into said axial bore. A hydraulic head is attached to the pump body and a displacement plunger extends from the hydraulic head through the axial bore. A hydraulic circuit attached to the hydraulic head and operated the same to reciprocate the displacement plunger within the axial bore. A fluid discharge conduit is connected to the fluid discharge port and a first check valve is connected inline therewith to allow fluid to flow in only one direction out of the fluid discharge port and into a lift

tube connected the fluid discharge conduit. A second check valve connected to said fluid inlet port to allow formation fluid to flow in one direction into the axial bore and a vent valve is attached to the vent port for venting gas therethrough and out of the axial bore.

[Para 13] There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood and in order that the present contribution to the art may be better appreciated.

[Para 14] Numerous objects, features and advantages of the present invention will be readily apparent to those of ordinary skill in the art upon a reading of the following detailed description of presently preferred, but nonetheless illustrative, embodiments of the present invention when taken in conjunction with the accompanying drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of descriptions and should not be regarded as limiting.

[Para 15] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

[Para 16] For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[Para 17] The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

[Para 18] Figure 1a is a diagrammatic view of the preferred embodiment of the method and apparatus for removing fluids from wells constructed in accordance with the principles of the present invention;

[Para 19] Figure 1b is a detailed diagrammatic view of the hydraulic control system;

[Para 20] Figure 2a is a side elevation view of a first embodiment of a pump apparatus of the present invention shown in a first position;

[Para 21] Figure 2b is a side elevation view of the pump apparatus of Figure 2a shown in a second position;

[Para 22] Figure 3a is a side elevation view of a second embodiment of the pump apparatus of the present invention shown in a first position; and

[Para 23] Figure 3b is a side elevation view of the pump apparatus of Figure 3a shown in a second position.

[Para 24] The same reference numerals refer to the same parts throughout the various figures.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[Para 25] Referring now to the drawings, and particularly to Figures 1a-3b, a preferred embodiment of the pump apparatus 10 is illustrated. With reference to Figure 1a, the pumping apparatus 10 is employed to lift formation fluid 12 from the well 14 to "unload" the well and restore it back to flow production. The formation fluid 12 can be water, oil or any other liquid gas mixture which is present downhole the well 14 to be pumped from one location to another. In addition, while the pump apparatus 10 is shown to be lifting the formation fluid 12 from a conventional gas well 14, the pump apparatus 10 will work as well in any other environment where its particular features would be beneficial.

[Para 26] The pump apparatus 10 essentially includes a pump body 18, a hydraulic head 20 connected to the pump body, a reciprocating displacement plunger 22 connected to and operated by the hydraulic head 20 to reciprocate within the pump body to draw-in formation fluid 12 and displace it from the pump body to the surface of the well 14.

[Para 27] The hydraulic head 20 is connected to a hydraulic circuit 24 having a prime mover 26 which is positioned at the surface of the well 14. The prime mover 26 can be of any know device for establishing pressure within the hydraulic lines of a hydraulic system, such as a pump. Due to the design of the pump apparatus 10, the power requirements to operate the pump apparatus are very low and can be supplied by one of a numerous sources, such as a small portable electric generator or preferable, a solar energy conversion system 15.

[Para 28] A more detailed explanation of the hydraulic circuit 24 can be had with reference to Figure 1b. The hydraulic circuit 24 includes a prime mover 26, a hydraulic valve assembly 27, and a pair hydraulic cylinders 29a and 29b that are fitted with floating pistons. The prime mover 26 is connected to the hydraulic valve assembly 27 and the hydraulic cylinders 29a and 29b are connected in parallel between the hydraulic valve assembly and the hydraulic head 20. The hydraulic valve assembly 27 is operative, manually or by automation to control the sequential pressurization and depressurization of each hydraulic cylinder 29a and 29b by the prime mover 26. The hydraulic circuit 24 utilizes two separate working fluids, one working fluid is utilized on the prime mover 26 side of the hydraulic cylinders 29a and 29b and the second working fluid is utilized on the hydraulic head 20 side of the hydraulic cylinders. The second working fluid is ideally a low viscosity fluid, such as diesel fuel. Diesel fuel is desired as the second working fluid because it has a low viscosity at low temperatures and also has some lubrication characteristics that allow for minimum wear on various components of the pump 10. The use a low viscosity fluid as the second working fluid allows the control lines 70 or capillary lines to be of a lesser diameter, thus reducing expense and weight of the system.

[Para 29] The design of the hydraulic pump 10 does not require the circulation of the working fluid for the operation of the pump, as such the hydraulic cylinders 29a and 29b which are fitted with floating pistons seal the first working fluid, such as the hydraulic oil used in the prime mover 26 from the second working fluid used to reciprocate the displacement plunger 22. Additionally, the hydraulic cylinders 29a and 29b are constructed of a sufficient volume to compensate for temperature variations within the second working fluid.

[Para 30] Referring now to Figure 2a, the construction of the pump apparatus 10 will be described in more detail. The pump body 18 has an axial bore 28

defining a first chamber 30, a diametrically reduced section 32, and a second chamber 34. At least one gas vent port 36 is formed through the side wall 38 of the pump body 18 and into the first chamber 30. Preferably, the gas vent port 36 is formed through the side wall 38 normal to the axial bore 28. A fluid in-let port 40 is formed through the side wall 38 of the pump body 18 and into the second chamber 34. Preferably, the fluid in-let port 40 is formed through the side wall 38 normal to the axial bore 28. A fluid discharge port 42 is also formed through the pump body 18 and into the second chamber 34. Preferably, the fluid discharge port 42 is formed axially through an end 44 the pump body 18.

[Para 31] The hydraulic head 20 is attached to the pump body 18 opposite of end 44 and the displacement plunger 22 extends from the hydraulic head into the axial bore 28 through the first chamber 30, the diametrically reduced section 32 and into the second chamber 34. The displacement plunger 22 seals the first chamber 30 from the second chamber 34 when passed through the diametrically reduced section 32. A seal 46 is positioned between the displacement plunger 22 and the diametrically reduced section 32 to insure the first chamber 30 and the second chamber 34 remained sealed from on another. Preferable the stroke of the displacement plunger 22 is about equal to the length of the second chamber 34. The stroke of the displacement plunger 22 is such, when in a fully retracted position the end 48 thereof is flush with the diametrically reduced section 32 on the second chamber 34 side, as illustrated in Figure 2a. When the displacement plunger 22 is in a fully extended position, the end 48 is in close tolerance to the end 50 of the second chamber 34.

[Para 32] Preferably, the diameter of the displacement plunger 22 is less then the diameter of the axial bore 28 so that the displacement plunger does not contact the surface of the axial bore to reduce wear and to eliminate the need to lubricate the displacement plunger.

[Para 33] A vent passage 52 is formed through the end 48 of the displacement plunger 22 such that fluid, gas or air is allowed to pass through the end 48 and out of the gas vent port 36 when the displacement plunger is in the fully retracted position as shown in Figure 2a.

[Para 34] A fluid discharge conduit 54 is attached to the fluid discharge port 42 and includes a first check valve 56 connected in-line therewith to allow formation fluid 12 displaced from the pump body 18 by the displacement pump to only flow in one direction through the discharge conduit and to prevent backflow of the formation fluid into the pump body, which has already been displaced by the displacement plunger. A lift tube 58 is provided and is in connected to the discharge conduit 54 to carry the formation fluid 12 to the surface of the well 14. A second check valve 60 is connected to the fluid in-let port 40and allows formation fluid only flow into the pump body 18 through the fluid in-let port.

[Para 35] Additionally, the pump apparatus 10 can include a casing 62 enclosing the pump body 18, the hydraulic head 20, and any other element of the pump apparatus as so desired within an interior volume 64. Preferable, all of the elements are enclosed by the casing 62 and positioned within the interior volume thereof. The casing 62 including a pair of fluid passages 66 which are formed through the sidewall 68 of the casing placing the interior volume 64 of the casing in fluid communication with the well 14. Most preferably, the pair of fluid passages 66 are formed through the casing 62 at opposite ends thereof.

[Para 36] When the casing 62 is included in the pump apparatus 10, the lift tube 58 is connected to the exterior of the casing and is sealed from the interior volume 64 thereof, with the fluid discharge conduit 54 connected to the lift tube and the hydraulic control lines 70 run down the lift tube and connect to the hydraulic head 20.

[Para 37] Referring now to Figures 2a and 2b, the pump apparatus 10 is preferably placed downhole below or about the perforations 72 of the well 14 and into a column of formation fluid 12. The displacement plunger 22 is first fully retracted establishing fluid communication between the first chamber 30 and the second chamber 34 by the vent passage 52 formed into the displacement plunger. In this position, formation fluid 12 is hydrostatically forced by well pressure into the pump body 18 through the fluid in-let port 40 and into the second chamber 34. If any gas is admixed with the formation fluid 12 it flows from the second chamber 34 through the vent passage 52 into the first chamber 30 and then out of the gas vent port 36. The displacement plunger is held in the retracted position for a predetermined time that is sufficient for a desired volume of formation fluid 12 to collect within the second chamber 34.

[Para 38] When the predetermined time as been met, the displacement plunger 22 is operated by the hydraulic head 20 and is extended into the second chamber 34. As the displacement plunger 22 travels into the second chamber 34, the first chamber 30 and the second chamber are fluidically disconnected and the formation fluid 12 present within the second chamber is displaced by the displacement plunger out of the fluid discharge port 42, into the fluid discharge conduit 54, and then into the lift tube 58, where it travels to the surface of the well 14.

[Para 39] Once the displacement plunger 22 has completed the stroke, it is then reset into the retracted position and the cycle is reinitiated. The pump apparatus 10 is operated in this manner until enough formation fluid 12 is lifted from the well to “unload” the well and reestablish gas production from the well.

[Para 40] Referring now to Figures 3a and 3b, a second embodiment of the pump apparatus 10 is illustrated and will be described. In this embodiment, the pump apparatus 10 is of the basic construction as the first embodiment and includes a pump body 18, a hydraulic head 20 connected to the pump body, and a reciprocating displacement plunger connected to and operated by the hydraulic head 20 to reciprocate within the pump body to draw-in formation fluid 12 and displace it from the pump body to the surface of the well 14. The main difference between the first and second embodiments is the first chamber 30, the diametrically reduced section 32, and the second chamber 34 are eliminated in the second embodiment, and a vent valve is added to control the venting of formation fluid 12 from the pump body 18.

[Para 41] More particularly in the second embodiment, the pump body 18 has an axial bore 28, a gas vent port 36 formed through the side wall 38 of pump body, a fluid in-let port 40 formed through the side wall, and a fluid discharge port 42 formed through the side wall. Most preferably, the gas vent port 36 is formed through the side wall 38 normal to the axial bore 28, the fluid in-let port 40 is formed through the side wall 38 normal to the axial bore 28, and the fluid discharge port 42 is formed axially through an end 44 of the pump body 18.

[Para 42] The hydraulic head 20 is attached to the pump body 18 opposite of end 44 and the displacement plunger 22 extends from the hydraulic head into the axial bore 28. Preferable the stroke of the displacement plunger 22 is about equal to the length of the axial bore 28. Most preferably, the diameter of the displacement plunger 22 is less then the diameter of the axial bore 28 so that the displacement plunger does not contact the surface of the axial bore to reduce wear and to eliminate the need to lubricate the displacement plunger.

[Para 43] A fluid discharge conduit 54 is attached to the fluid discharge port 42and includes a first check valve 56 connected in-line therewith to allow formation fluid 12 displaced from the pump body 18 by the displacement pump to only flow in one direction through the discharge conduit and to prevent backflow of the formation fluid into the pump body.

[Para 44] A lift tube 58 is provided and is in connected to the discharge conduit 54 to carry the formation fluid 12 to the surface of the well 14. A second check valve 60 is connected to the fluid in-let port 40 and allows formation fluid only flow into the pump body 18 through the fluid in-let port. A vent valve 74 is attached to the gas vent port 36 and is operative to control venting of fluid from the gas vent. Preferably, the vent valve 74 is a normally closed valve and is operated to open based upon a predetermined pressure present within the hydraulic circuit 24.

[Para 45] As in the previous embodiment, the pump apparatus 10 can also optionally include a casing 62 enclosing the pump body 18, the hydraulic head 20, and any other element of the pump apparatus as so desired within an interior volume 64. Preferable, all of the elements are enclosed by the casing 62 and positioned within the interior volume thereof. The casing 62 including a pair of fluid passages 66 which are formed through the sidewall 68 of the casing placing the interior volume 64 of the casing in fluid communication with the well 14. Most preferably, the pair of fluid passages 66 are formed through the casing 62 at opposite ends thereof.

[Para 46] When the casing 62 is included in the pump apparatus 10, the lift tube 58 is connected to the exterior of the casing and is sealed from the interior volume 64 thereof, with the fluid discharge conduit 54 connected to the lift tube and the hydraulic control lines 70 run down the lift tube and connect to the hydraulic head 20.

[Para 47] In operation, the displacement plunger 22 is first set at a full retracted position for a predetermined time and formation fluid 12 is allowed to enter the pump body through the fluid in-let port 40. The hydraulic circuit 24 is pressurized to a predetermined pressure opening the gas vent port 36 to vent any gas admixed with the formation fluid drawn into the pump body.

[Para 48] When the predetermined time is met, the gas vent valve 74 is isolated and closed, and the displacement plunger 22 is operated by the hydraulic head 20 and is extended into the axial bore 28. As the displacement plunger is extended into the axial bore 28, the formation fluid 12 is displaced by the displacement plunger out of the fluid discharge port 42, into the fluid discharge conduit 54, and then into the lift tube 58, where it travels to the surface of the well 14.

[Para 49] Once the displacement plunger 22 has completed the stroke, it is then reset into the retracted position and the cycle is reinitiated. The pump apparatus 10 is operated in this manner until enough formation fluid 12 is lifted from the well to “unload” the well and reestablish gas completion from the well.

[Para 50] In either embodiment, the operation of the pump apparatus 10 can be a manual control through the incorporation of manually actuated valves in the hydraulic circuit 24, or preferably, a programmable logic controller 76 is used and is programmed to control the operation of hydraulic valve assembly 27. It is believed that no further discussion of the manual or controller operation of the pump apparatus is needed as it is in the knowledge of one of ordinary skill to incorporate such control systems into a hydraulic circuit to operate a hydraulic plunger.

[Para 51] A method of removing formation fluids from a well to “unload” the well is also provided. The method involves the steps of providing a

hydraulically operated fluid displacement pump connected to a hydraulic circuit, positioning the fluid displacement pump downhole, operating the fluid displacement pump intermittently to vent the pump of gas, load the pump with formation fluid and to discharge the formation fluid to the surface of the well. The displacement pump comprising any one of the two above described embodiments.

[Para 52] A number of embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.